Regional Studies in Marine Science 16 (2017) 240–248

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Spatial and temporal distribution of narwal shrimp *Plesionika narval* (Decapoda, Pandalidae) in the Aegean Sea (eastern Mediterranean Sea)

Stefanos Kalogirou[a,*], Aikaterini Anastasopoulou[a], Konstantinos Kapiris[a], Christos D. Maravelias[a], Mihalis Margaritis[a], Christopher Smith[a], Leif Pihl[b]

[a] *Hellenic Centre for Marine Research, Institute for marine biological resources and inland waters, Hydrobiological Station of Rhodes, Greece*
[b] *Department of biological and environmental sciences, University of Gothenburg, Kristineberg, Sweden*

ARTICLE INFO

Article history:
Received 17 August 2017
Received in revised form 24 September 2017
Accepted 25 September 2017
Available online 6 October 2017

Keywords:
Plesionika
Small-scale fishery
Eastern mediterranean
CPUE
Sex ratio

ABSTRACT

In the Aegean Sea the trap fishery for narwal shrimp, *Plesionika narval*, contributes to social and cultural cohesion of local fishery communities. Spatial and temporal distribution patterns of narwal shrimp was studied during an annual cycle, including catch per unit effort (CPUE), sex ratio and proportion of ovigerous females in the population. Shrimps were sampled at five localities within the depth range of 10 to 170 m. Catch per unit effort increased during the summer period at all depths, when seawater temperature increase. Differences in CPUE were observed between depths, with highest catches at depths below 70 m. The proportion of females decreased significantly with depth, a pattern especially evident during the summer period (May to August), indicating a migration of females to shallower waters. Significant higher abundance of ovigerous females was observed during the period May to October, concurrently with a vertical migration of females to warmer waters. To further support this pattern, the proportion of ovigerous individuals among females increased with decreased depth at all seasons. We suggest that the findings of our study have significant implications to current and future management of narwal shrimp in the Mediterranean Sea.

1. Introduction

Small-scale trap-fisheries for narwal shrimp (*Plesionika narval*) (Fabricius, 1787) is one of the most profitable small-scale fisheries (SSF) in the Aegean Sea. Despite the importance of narwal shrimp fisheries for fishing communities around the Aegean Sea, scientific knowledge about this species distribution and sensitivity to climatic change remains scarce (Thessalou-Legaki, 1989, 1992; Thessalou-Legaki et al., 1989). A strong scientific knowledge base is crucial in order to develop a sustainable management strategy for the narwal shrimp fishery in the Aegean Sea, and give insights to other areas where small-scale trap fisheries are performed.

The narwal shrimp is included in the Fisheries and Agriculture Organization (FAO) catalogue of the species of interest in fisheries (Holthuis, 1980, 1987; Lagardere, 1981). In the eastern central Atlantic, fishing grounds are located in the upper regions of the continental slopes off Madeira, Canary Islands and Guinea-Bissau (González et al., 1997). The narwal shrimp has a high commercial value since it often forms sizeable concentrations and is easily fished with bottom traps (Biscoito, 1993; Castriota et al., 2004; Holthuis, 1987; Lagardere, 1981). Although narwal shrimp is an abundant, widespread, species of interest to fisheries in many regions (Chan and Crosnier, 1991), research only began during the 1990's on the occurrence, biology and fisheries of Pandalidae in Azores (Martins and Hargreaves, 1991), Madeira (Biscoito, 1993), Greece (Thessalou-Legaki, 1992; Thessalou-Legaki et al., 1989; Thessalou-Legaki, 1989) and the Canary Islands (Caldentey et al., 1992; González et al., 1988, 2001; Lozano et al., 1990a, b).

The geographical distribution of narwal shrimp extends from the eastern central Atlantic of the African coasts including Madeira, Canary Islands and the Cape Verdes (FAO fishing areas 34 and 47), throughout the south-western Iberian Peninsula, extending westward to the Azores eastwards, into the Mediterranean Sea and, and southwards to Angola (González et al., 1997; Landeira et al., 2009). Its geographical distribution also extends into the Red Sea and the western Indian Ocean (Seychelles, Madagascar, reunion) as well as the western central Pacific Ocean (Taiwan, Philippines, Indonesia, New Caledonia and Tahiti). (González et al., 1997). In the Mediterranean Sea, the narwal shrimp has been observed throughout the basin from its western (Spain, France) (Castriota et al., 2004; Fanelli et al., 2004) to its easternmost parts (Greece,

* Corresponding author.
E-mail addresses: stefanos.kalogirou@gmail.com, skalogirou@hcmr.gr (S. Kalogirou).

https://doi.org/10.1016/j.rsma.2017.09.014
2352-4855/

Cyprus, Turkey) (Carbonell and Abello, 1998; Christodoulou et al., 2009; Fransen, 2006; Koukouras et al., 1992; Thessalou-Legaki et al., 1989). The narwal shrimp may occur at depths between 2 m (Biscoito, 1993) and 910 m (Crosnier and Forest, 1973) and it also occurs in submarine caves (Arculeo and Lo Brutto, 2011; Crosnier and Forest, 1973; Holthuis, 1980, 1987; Lagardere, 1981).

Narwal shrimp are a nektobenthic species feeding on pelagic and benthic organisms, thus filling an important ecological function to benthic assemblages (Cartes et al., 2002; Kitsos et al., 2008). Furthermore, narwal shrimp constitute an important prey for demersal fish and cephalopods (Cartes, 1993a; Fanelli and Cartes, 2004). The narwal shrimp is a cosmopolitan species occurring from the surface down to 910 m of depth in a large variety of habitats including muddy, sand–muddy, rocky bottoms and submarine caves (Biscoito, 1993; Holthuis, 1987; Thessalou-Legaki et al., 1989). As shown for many crustaceans, the growth of narwal shrimp is affected by temperature and food availability (Sousa et al., 2014). Both in the northeastern Atlantic and the central Mediterranean Sea, ovigerous individuals have been found to occur all year round indicating a prolonged spawning period (Arculeo and Lo Brutto, 2011; Sousa et al., 2014; Triay-Portella et al., 2017). To our knowledge, information on temporal variations in CPUE within the geographical distribution range of the narwal shrimp have previously been limited to one study from the Azores (eastern Atlantic), where no seasonal variation was observed (Graca, 2008).

Narwal shrimp is the main target species of the small-scale trap-fishery at the narrow shelf and steep slopes of the south-eastern Aegean Sea. Fisheries in the studied area takes place from dusk to dawn with baited shrimp traps at depths from 5 m to 200 m, and deployed close to the bottom. Fisheries depths reported from the eastern central Atlantic were from 200 to 500 m. on cliffs of the continental shelf, or close to the deep zones associated with *Dendrophyllia sp*. (González et al., 1997). Although adult individuals inhabit a wide range of habitats including muddy, sandy and rocky bottoms. (González et al., 1997), the trap-fishery in the studied area is mainly undertaken over rocky bottoms to avoid setting traps in the mud.

Current trap fishery legislation prohibits trap size to exceed 50 cm in height, 1 m in diameter and 13 cm upper mouth opening. Additionally, a temporal ban period is set from May 1 to July 31, a depth ban prohibiting fishing at depths shallower than 10 m, while the maximum number of traps per fishing vessel cannot exceed 300 (Presidential decree 157/2004). As a measure to collect landing data and manage this fishery, temporary fishing licences were issued during the banned period and the years from 2005 to 2012 but data were scarce and limited.

This is the first quantitative study on narwal shrimp in the eastern Mediterranean Sea with the aim to study the population structure and dynamics through measurements on CPUE, sex ratio and occurrence of ovigerous females during an annual small scale fisheries survey. Population dynamics in the fishery were related to depth and seawater temperature to explain the observed patterns. Results are aimed to support management for the sustainable exploitation of narwal shrimp.

Ethics statement

Permission for the scientific sampling was approved by the Aegean Sea Administration, General Secretariat for Forestry and Agriculture, Greece.

2. Material and methods

2.1. Study area

The fishing survey was performed with commercial shrimp traps (FPO) at five island locations (Halki: 1, Symi: 2, Tilos: 3, Nisyros: 4, Karpathos: 5) in the Dodecanese archipelago of the south-eastern Aegean Sea (Fig. 1). Locations were selected based on primary fishery areas indicated from personal interviews with all active commercial fishermen in the area and logbooks provided by the fishery department. A multi-parameter probe CTD 75M Sea & Sun was used to collect monthly temperature profiles from 0 to 150 m in depth. A contour plot of temperature and depth along an annual cycle was used to illustrate thermocline formation. The sampling method of baited shrimp traps, used in this study, an along-bottom passive gear, was found to be highly effective in catching a wide size range of the narwal shrimp.

2.2. Sampling

Fishing took place overnight (20:00–08:00 h) on a monthly basis during an annual cycle from November 2014 to October 2015. Due to rough weather conditions, sampling was missed in February. Circular traps covered with nylon-based net of a mesh size of 12 mm (knot to knot), and with an upper trap opening of 13 cm were used. Two replicate lines with 25 traps were deployed at each of three depth strata (A: 10–30 m; B: 70–90 m and C: 150–170 m) at each location. Depth ranges were selected to study the narwal shrimp distribution above and below the 35–45 m summer thermocline depth.

Shrimps were attracted to the traps using a bait consisting of a mixture of minced oily fish (e.g., sardines and mackerel) stabilized with flour and water. The total length of the line was adjusted to fishing depth and 25 traps were attached to the ground line with a distance of 35 m between the traps along the bottom, following common fishery practice in the studied area. Each trap was attached to the ground line with another 2 m side rope. Equidistantly, floats were placed to hinder the line/rope from entangling while weights were used to keep the traps close to the bottom.

After a soak time of 12 h, traps were collected and the catch was sorted on-board into target species, bycatch and discards and kept on ice until transported to the lab. Soak time reflects the fishery in the studied area. Total shrimp catch was identified to species level. From a random subsample of 200 individuals per fishing line, sex was determined and divided into males, females and ovigerous while carapace length, (C_L, mm) and wet weight (Ww, g) were measured.

2.3. Interactions among investigated parameters

To clarify the relationship between parameters a screeplot and Principal Component Analysis (PCA) was applied.

2.4. Variation in catch per unit effort (CPUE)

Catch per unit effort (CPUE) was expressed as kg/25 traps. Spatial (location and depth) and temporal (monthly) variation in CPUE was used to investigate population structure and dynamics. Temporal and spatial variation in CPUE was investigated with a parametric three-way nested Analysis of Variance (ANOVA). To model annual variations General Additive Model (GAM) was used with R (R-Core-Team, 2015), applying a LOESS smoothing curve to aid the visual interpretation of spatial variations in CPUE between localities.

2.5. Analysis of variance

Prior to ANOVA, outliers were investigated with histograms and QQ-plots. We used CPUE as the response variable and month, location and depth as the factors. Following ANOVA, Tukey's Honest Significance Difference (HSD) test was applied to reveal differences between explanatory variables. In addition, LOESS smoothing curves were applied aiding the visual interpretation of spatial variations in CPUE between localities.